PATENT SPECIFICATION 820,885

DRAWINGS ATTACHED.

Inventors:—HENRY DE BOYNE KNIGHT and NORMAN ROBERT MCCORMICK.

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International Classification:—H01j.

COMPLETE SPECIFICATION.

Improvements in Control Electrodes for Gas-Filled Electric Discharge Devices.

We, THE BRITISH THOMSON - HOUSTON COMPANY LIMITED, a British Company, having its registered office at Crown House, Aldwych, London, W.C.2, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to electrostatically controlled gaseous electric discharge devices of the kind generally known as thyratrons.

The control electrode in an electric discharge device of this kind is, as is well known, capable of preventing the passage of a discharge between a thermionic cathode and an anode when the anode is positive with relation to the cathode, but loses control over the discharge after the discharge has been initiated, except under conditions which are not usual in present day thyratron practice.

The voltage necessary to prevent the discharge to the anode from starting depends on the design of the control electrode, which customarily includes an apertured baffle arranged to intercept the discharge path between cathode and anode.

Thus, referring to the accompanying drawings, Fig. 1 thereof illustrates diagrammatically the essential parts of an electrode structure for a thyratron. In this Figure, 1 represents the cathode (heated by means not shown), 2 the anode, and the control electrode consists of a sheet metal cylinder 3 to which is attached a cross baffle 4, which may be of sheet metal, graphite or other suitable material, which is apertured for the passage of the arc. Various forms of aperture have hitherto been employed for the baffle. Thus in that shown in Fig. 2 there is a single central aperture 5, corresponding with the cross-section illustrated in Fig. 1. The larger the diameter of the aperture, the greater the current carrying capacity thereof; but the greater the diameter of the aperture, the greater is the time required for deionisation and the greater the negative voltage required on the control electrode to hold off the arc when anode voltage is applied. Both these disadvantages may be overcome by the use of a plurality of separate small apertures, as shown at 6 in Fig. 3. The actual value of the negative voltage required for control depends on the nature and pressure of the gas and vapour, as well as on the dimensions of the aperture or apertures, and electrode spacings. In one standard design, a group of 26 circular holes about $\frac{1}{4}''$ in diameter in a baffle $^1/_{16}''$ thick and $1\frac{3}{4}''$ in diameter enables the thyratron to be held non-conducting by a negative potential of less than 10 volts on the control electrode when a positive voltage of 15,000 volts is applied to the anode.

A similar result may be obtained when the apertures are in the form of slots as shown at 7 in Fig. 4. The control ratio, i.e. the ratio of the anode voltage to the corresponding negative control electrode voltage required to prevent the striking of an arc, is a function of the greatest distance that any point in the aperture can be from the boundary of the aperture; in a slot of uniform shape this is half the slot width w as shown in Fig. 4. The requirements of control and of deionisation set the diameter of the holes in Fig. 3 or the slot width w in Fig. 4. The total aperture area, and hence the

current-carrying capacity, is determined by the number of holes or total length of slot which can be accommodated within the diameter d fixed upon as suitable for a particular design.

A disadvantage of the arrangements of Figs. 3 and 4 is that, when an arc strikes, it may do so through only one aperture, and as the current increases the current density in that aperture may reach a value corresponding to a somewhat high voltage drop (anode to cathode) before the arc commences to flow in a second aperture; quite often only a small fraction of the available apertures are in use even at full rated peak current. This leads to local overheating of the baffle containing the apertures and also of the anode due to the concentration of the arc in a few spots.

One method of obviating this difficulty is shown in Fig. 5; here the aperture is in the form of an annular slot formed by the spacing between the outer rim of baffle 4 and an inner metal disc 8. The disc 8 may be held to 4 by a single bridge piece 9, or by one or more supports (insulating if desired) in a different plane so as not to obstruct the arc passage through the slot. It is not important, whether both 4 and 8 are at the same potential; either may, for example, be at cathode potential, the controlling potential being applied to the other.

The advantage of such an arrangement resides in the fact that while the current-carrying capacity of the aperture is increased as a result of its large area, the control ratio remains high as a result of the narrowness of the aperture, as above explained.

The object of the invention is to provide an improved arrangement giving increased current-carrying capacity without diminishing the control ratio.

According to the invention an electrostatically controlled electric discharge device comprises an electron emitting cathode, an anode, and a cylindrical discharge control member providing barrier means interposed in the path of the arc between the cathode and the anode, the barrier member possessing an aperture for the passage of the arc, and a further baffle electrode interposed in the path of the arc between the barrier member and the cathode, the aperture in the barrier member being in the form of a continuous single slot the total area of which is at least 25% more than the maximum area obtainable with a single slot of annular form and having a width w determined by the required control ratio and a diameter limited by the dimension of the baffle or barrier member.

In the simple type of thyratron construction illustrated in Fig. 1 this dimension is limited only by the diameter of the control electrode, assuming that, as is usual in electrode constructions for electric arc discharge devices of the thyratron type, the electrodes are coaxially mounted and are of circular symmetry. Thus, if the control electrode is in the form of a hollow cylinder and the barrier member or baffle is in the form of a disc arranged transversely of the hollow cylindrical control electrode, the disc may have, in the limit, a diameter less by 2 w than the internal diameter of the cylinder, leaving an annular space of width w between the rim of the baffle and the interior cylindrical surface of the control electrode.

In an arrangement according to the invention, capable of use in gas-filled thyratrons employed as radar modulator valves, which is illustrated in Fig. 6, one or more cross baffles are inserted between the apertured baffle or barrier member 4 and the cathode 1. In Fig. 6 the apertured baffle 4 is one of the types illustrated in Figs. 7—13. Between this and the cathode is a further cross baffle 4a (or a plurality of baffles) which may be connected to any desired potentials according to the design. The outer diameter of the annular slot in such cases is normally smaller than the maximum diameter of the baffle (or baffles) 4a. The control characteristic of the valve is determined by the width w of the aperture, by the axial spacings of the anode and the various baffles from one another, and by the diameter of the baffle 4a and that of the aperture. The diameter of baffle 4a is further limited by the spacing required between it and the cylinder 3 for the passage of the arc. Thus, the diameter chosen for baffle 4a to fulfil the required control conditions fixes also the maximum possible value of the diameter of the annular aperture.

The area of the aperture provided by the present invention must, therefore, be such that, adhering to the width w, the total area provided must be at least 25% greater than the area of such annular slot. The apertures may thus be in the form of a continuous slot of sinuous form or one having at least one complete substantially circular convolution, said convolution having its area increased without involving any material increase in the width w of the aperture (and consequently of the control ratio insofar as it is affected by this dimension) by extending the slot lengthwise or transversely.

Thus the slot may then comprise a multi-turn spiral of substantially uniform width, or an annular slot having slots of the same width arranged substantially radially with respect to and joining with the annular slot; there is thus provided an arrangement in which the maximum distance of any point within the aperture is substantially no greater than half the width of the spiral or annular slot. The slot will thereby be made to possess a total area greater by 25% than

that of the maximum obtainable with a single annular slot, as above mentioned.

Several embodiments of the apertured baffle used in accordance with the invention will now be illustrated in connection with Figs. 7 to 13 of the accompanying drawings.

In the arrangement shown in Fig. 7, the baffle portion 4 is provided with a slot 10 in the form of a continuous spiral. The design of the slot is determined by a desired value of its width w and of the available space of diameter d in which the slot is located. The length of slot which can be accommodated is thus a function of the width of the conducting part between adjacent turns of the spiral; this width will be related to the need for adequate heat conduction from the parts of the metal forming the boundary of the aperture. Thus, in the arrangement illustrated in Fig. 8, the aperture 11 is shown as formed between the turns of a spiral 12 of wire or of strip wound on edge. The part 12 may be held at one end 13, for example, by welding, to the annular washer 4, or by supports (not shown) in a different plane. Also it may, if desired, be insulated from the washer 4; parts 12 and 4 can then be at different potentials during operation of the thyratron.

The slot aperture need not be in spiral shape as shown in Figs. 7 and 8, but may be in a series of hair-pin bends, or any other shape which will give the required area in one continuous aperture within the usable area. A substantially spiral design has the advantage of tending to give symmetry in coverage of the anode for a given value of arc current when the whole aperture is not filled.

Another arrangement which fulfils the required conditions is the association of an annular aperture of width w with a series of slots, also of width w leading from it. In the embodiment shown in Fig. 9 the annular aperture 14 is formed between a central disc 15 and the washer 4, and slots 16, 17 radiate inwards from it. In the embodiment of Fig. 10, the inverse arrangement is shown the slots 20 radiating outwards from the annular aperture 18 formed with the central disc 19. The apertures are shown as radial in each case, but they are not necessarily so.

The effect of Figs. 9 and 10 may be produced by fixing conducting elements projecting inwards from an outer washer, or *vice versa*. Such constructions are shown in Figs. 11 and 12. In Fig. 11 conductors 23 (shown as wires or strips on edge) fixed to washer 4 project inwards into the annular space 22 between 4 and the centre washer 21 and to a distance w from the latter. The adjacent conductors 23 may not produce a parallel sided aperture, but the best spacing of the conductors, which will be approximately w, will be determined empirically. Fig. 12 shows the case in which conductors 24 fixed to a centre washer 21 project outwards into the annular aperture 22 between 21 and the washer 4.

A variant of this design is shown in Fig. 13 in which conductors 23 and 24 project alternately into the aperture 22 between centre washer 21 and outer washer 4.

In connection with Fig. 5 it was explained that the aperture is formed between the outer washer 4 and a centre member, and that these two may be joined together at only one point in their plane, or at one or more points in a different plane, the supports being insulating if desired. Further, these two members need not be at the same potential; either may be connected to a fixed potential, for example, while the other carries a potential which is varied for purposes of control. The same considerations apply also to the separate parts between which the aperture is formed in Figs. 9 and 13 inclusive.

WHAT WE CLAIM IS :—

1. An electrostatically controlled electric arc discharge device comprising an electron-emitting cathode, an anode, and a cylindrical discharge control member providing barrier means interposed in the path of the arc between the cathode and the anode, the barrier member possessing an aperture for the passage of the arc, and a further baffle electrode interposed in the path of the arc between the barrier member and the cathode, the aperture in the barrier member being in the form of a continuous slot having a width w substantially uniformly distributed over the area of the barrier member and possessing an area at least 25% more than the maximum area obtainable with a single slot of annular form having a width w determined by the required control ratio and a diameter the maximum allowable by the diameter of said barrier member and by the relation between the barrier member and the further baffle.

2. An electrostatically controlled electric arc discharge device as claimed in Claim 1, in which the continuous slot is of spiral configuration having at least one complete convolution and extending over substantially the whole area of the barrier member.

3. An electrostatically controlled electric arc discharge device as claimed in Claim 1, in which the slot is of annular form having equi-angularly spaced radial slots extending from the periphery thereof, said radial slots having a width substantially equal to that of said annular slot.

4. An electrostatically controlled electric arc discharge device as claimed in Claim 1, in which the slot is in the form of an annulus having projecting from the inner periphery thereof conducting elements which

cause the permissible part of the arc through the slot to be of sinuous form.

5. An electrostatically controlled electric arc discharge device substantially as described and with reference to Figs. 6 to 13 of the accompanying drawings.

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PROVISIONAL SPECIFICATION.

Improvements in Control Electrodes for Gas-Filled Electric Discharge Devices.

We, THE BRITISH THOMSON - HOUSTON COMPANY LIMITED, a British Company, having its registered office at Crown House, Aldwych, London, W.C.2, do hereby declare this invention to be described in the following statement :—

This invention relates to electrostatically controlled gaseous electric discharge devices of the kind generally known as thyratrons.

The control electrode in an electric discharge device of this kind is, as is well known, capable of preventing the passage of a discharge between a thermionic cathode and an anode when the anode is positive with relation to the cathode, but loses control over the discharge after the discharge has been initiated, except under conditions which are not usual in present day thyratron practice.

The voltage necessary to prevent the discharge to the anode from starting depends on the design of the control electrode, which customarily includes an apertured baffle arranged to intercept the discharge path between cathode and anode.

Thus, referring to the accompanying drawings, Fig. 1 thereof illustrates diagrammatically the essential parts of an electrode structure for a thyratron. In this Figure, 1 represents the cathode (heated by means not shown), 2 the anode, and the control electrode consists of a sheet metal cylinder 3 to which is attached a cross baffle 4, which may be of sheet metal, graphite or other suitable material, which is apertured for the passage of the arc. Various forms of aperture have hitherto been employed for the baffle. Thus in that shown in Fig. 2 there is a single central aperture 5, corresponding with the cross-section illustrated in Fig. 1. The larger the diameter of the aperture, the greater the current carrying capacity thereof; but the greater the diameter of the aperture, the greater is the time required for deionisation and the greater the negative voltage required on the control electrode to hold off the arc when anode voltage is applied. Both these disadvantages may be overcome by the use of a plurality of separate small apertures, as shown at 6 in Fig. 3. The actual value of the negative voltage required for control depends on the nature and pressure of the gas and vapour, as well as on the dimensions of the aperture or apertures, and electrode spacings. In one standard design, a group of 26 circular holes about $\frac{1}{4}''$ in diameter in a baffle $^{1}/_{16}''$ thick and $1\frac{3}{4}''$ in diameter enables the thyratron to be held non-conducting by a negative potential of less than 10 volts on the control electrode when a positive voltage of 15,000 volts is applied to the anode.

A similar result may be obtained when the apertures are in the form of slots as shown at 7 in Fig. 4. The control ratio, i.e. the ratio of the anode voltage to the corresponding negative control electrode voltage required to prevent the striking of an arc, is a function of the greatest distance that any point in the aperture can be from the boundary of the aperture; in a slot of uniform shape this is half the slot width w as shown in Fig. 4. The requirements of control and of deionisation set the diameter of the holes in Fig. 3 or the slot width w in Fig. 4. The total aperture area, and hence the current-carrying capacity, is determined by the number of holes or total length of slot which can be accommodated within the diameter d fixed upon as suitable for a particular design.

A disadvantage of the arrangements of Figs. 3 and 4 is that, when an arc strikes, it may do so through only one aperture, and as the current increases the current density in that aperture may reach a value corresponding to a somewhat high voltage drop (anode to cathode) before the arc commences to flow in a second aperture; quite often only a small fraction of the available apertures are in use even at full rated peak current. This leads to local overheating of the baffle containing the apertures and also of the anode due to the concentration of the arc in a few spots.

One method of obviating this difficulty is shown in Fig. 5; here the aperture is in the form of an annular slot formed by the spacing between the outer rim of baffle 4 and an inner metal disc 8. The disc 8 may be held to 4 by a single bridge piece 9, or by

one or more supports (insulating if desired) in a different plane so as not to obstruct the arc passage through the slot. It is not important, whether both 4 and 8 are at the same potential; either may, for example, be at cathode potential, the controlling potential being applied to the other.

The advantage of such an arrangement resides in the fact that while the current-carrying capacity of the aperture is increased as a result of its large area, the control ratio remains high as a result of the narrowness of the aperture, as above explained.

The object of the invention is to provide an improved arrangement giving increased current-carrying capacity without diminishing the control ratio.

According to the invention a continuous aperture is provided in the baffle portion of the control electrode of a thyratron, which aperture is in the form of a continuous slot of sinuous form or one having at least one complete substantially circular convolution, said convolution having its area increased without involving any material increase in the width of the aperture (and consequently of the control ratio insofar as it is affected by this dimension) by extending the slot lengthwise or transversely.

Thus the slot may then comprise a multi-turn spiral of substantially uniform width, or an annular slot having slots of the same width arranged substantially radially with respect to and joining with the annular slot; there is thus provided an arrangement in which the maximum distance of any point within the aperture is substantially no greater than half the width of the spiral or annular slot.

Several arrangements in accordance with the invention will now be illustrated in connection with Figs. 6 to 12 of the accompanying drawings.

In the arrangement shown in Fig. 6, the baffle portion 4 is provided with a slot 10 in the form of a continuous spiral. The design of the slot is determined by a desired value of its width w and of the available space of diameter d in which the slot is located. The length of slot which can be accommodated is thus a function of the width of the conducting part between adjacent turns of the spiral; this width will be related to the need for adequate heat conduction from the parts of the metal forming the boundary of the aperture. Thus in the arrangement illustrated in Fig. 7, the aperture 11 is shown as formed between the turns of a spiral 12 of wire or of strip wound on edge. The part 12 may be held at one end 13, for example by welding, to the annular washer 4, or by supports (not shown) in a different plane. Also it may, if desired, be insulated from the washer 4; parts 12 and 4 can then be at different potentials during operation of the thyratron.

The slot aperture need not be in spiral shape as shown in Figs. 6 and 7, but may be in a series of hair-pin bends, or any other shape which will give the required area in one continuous aperture within the usuable area. A substantially spiral design has the advantage of tending to give symmetry in coverage of the anode for a given value of arc current when the whole aperture is not filled.

Another arrangement which fulfils the required conditions is the association of an annular aperture of width w with a series of slots, also of width w leading from it. In the embodiment shown in Fig. 8 the annular aperture 14 is formed between a central disc 15 and the washer 4, and slots 16, 17 radiate inwards from it. In the embodiment of Fig. 9, the inverse arrangement is shown, the slots 20 radiating outwards from the annular aperture 18 formed with the central disc 19. The apertures are shown as radial in each case, but they are not necessarily so.

The effect of Figs. 8 and 9 may be produced by fixing conducting elements projecting inwards from an outer washer, or *vice versa*. Such constructions are shown in Figs. 10 and 11. In Fig. 10 conductors 23 (shown as wires or strips on edge) fixed to washer 4 project inwards into the annular space 22 between 4 and the centre washer 21 and to a distance w from the latter. The adjacent conductors 23 may not produce a parallel sided aperture, but the best spacing of the conductors, which will be approximately w, will be determined empirically. Fig. 11 shows the case in which conductors 24 fixed to a centre washer 21 project outwards into the annular aperture 22 between 21 and the washer 4.

A variant of this design is shown in Fig. 12 in which conductors 23 and 24 project alternately into the aperture 22 between centre washer 21 and outer washer 4.

In connection with Fig. 5 it was explained that the aperture is formed between the outer washer 4 and a centre member, and that these two may be joined together at only one point in their plane, or at one or more points in a different plane, the supports being insulating if desired. Further, these two members need not be at the same potential; either may be connected to a fixed potential, for example, while the other carries a potential which is varied for purposes of control. The same considerations apply also to the separate parts between which the aperture is formed in Figs. 8 and 12 inclusive.

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Fig.1.

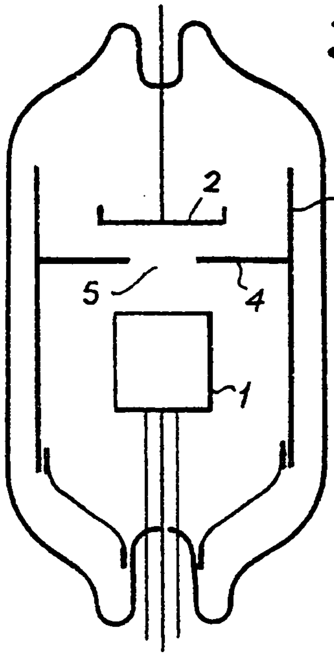


Fig.6.

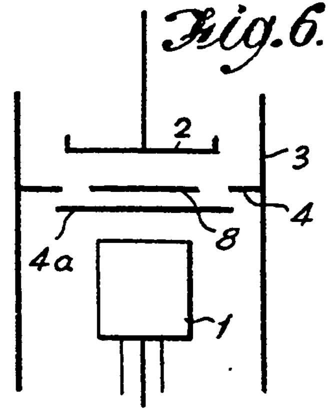


Fig.2

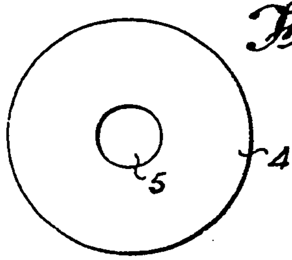
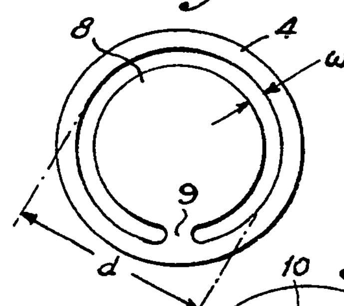


Fig.5.



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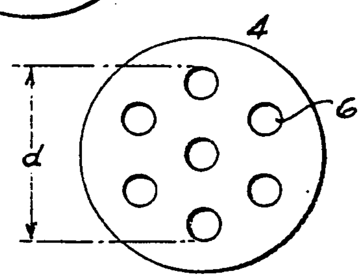
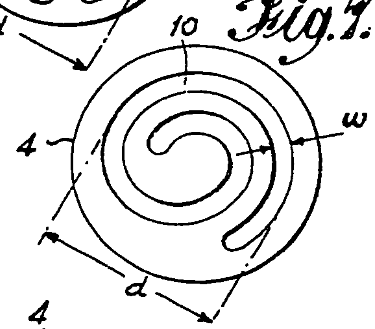


Fig.7.



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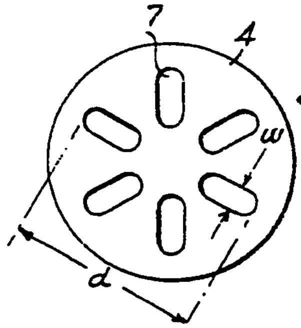

Fig.8.

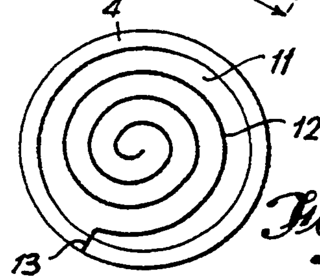

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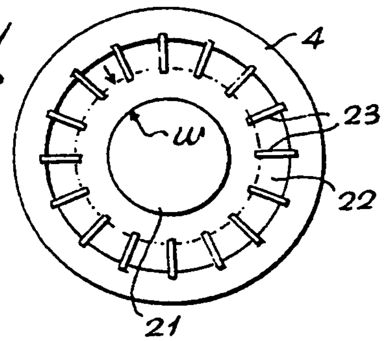
Fig.11.



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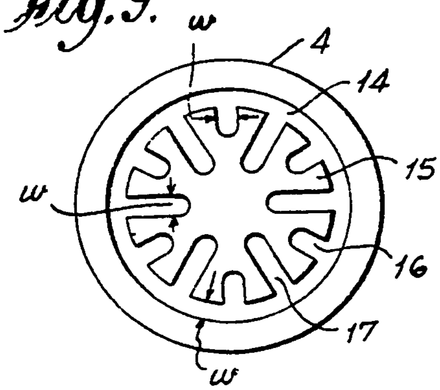

Fig.12

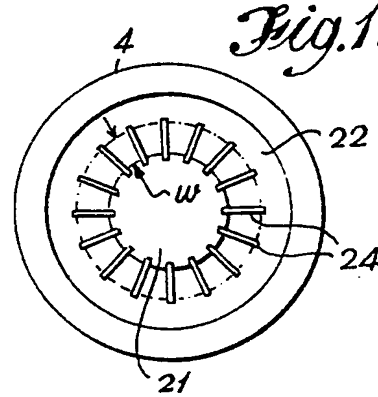

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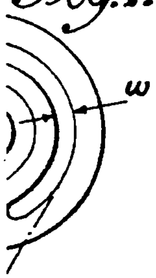
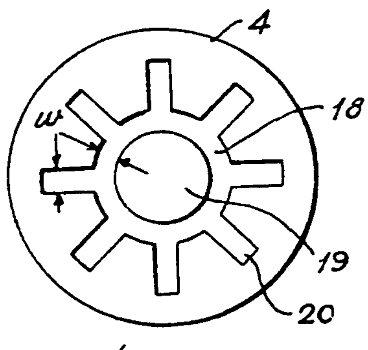
Fig.7.





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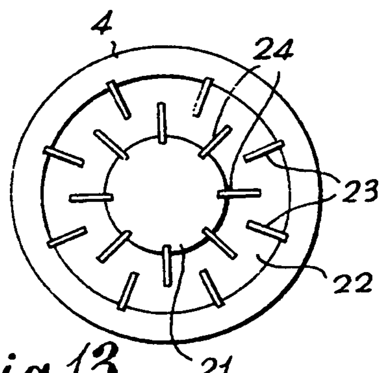

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Fig.13.

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SHEETS 1 & 2

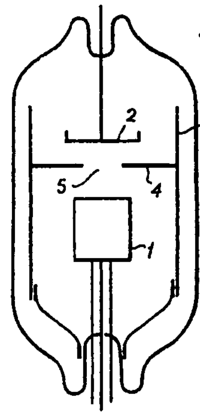


Fig.1.

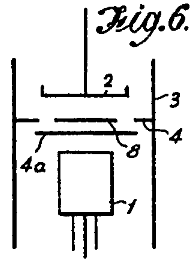


Fig.6.

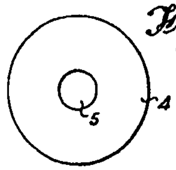
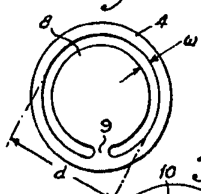


Fig.2



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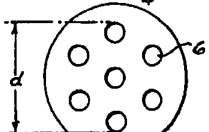
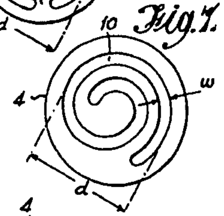


Fig.3.



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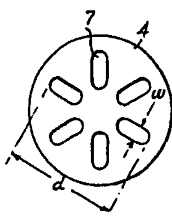


Fig.4.

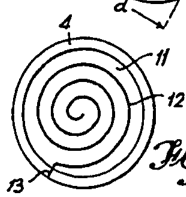


Fig.8.

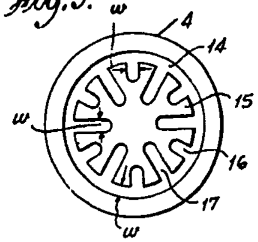


Fig.9.

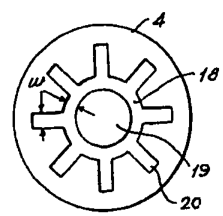


Fig.10.

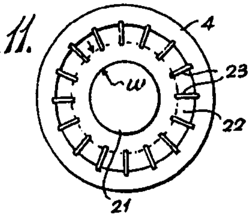


Fig.11.

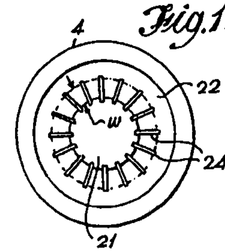


Fig.12

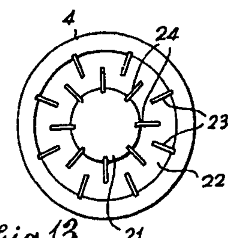


Fig.13.

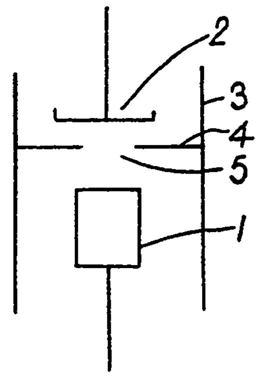


FIG. 1.

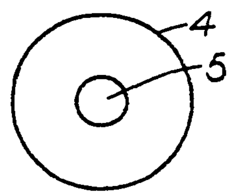


FIG. 2.

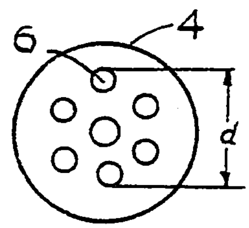


FIG. 3.

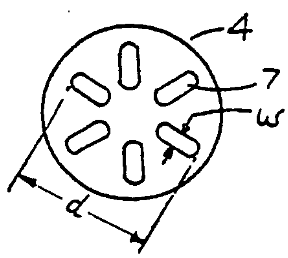
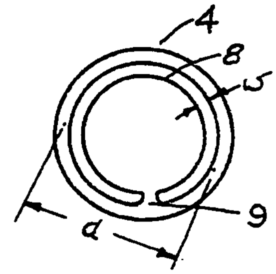


FIG. 4.



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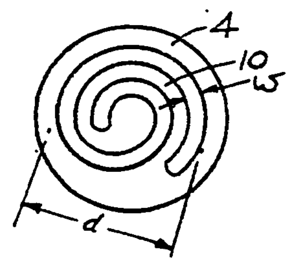

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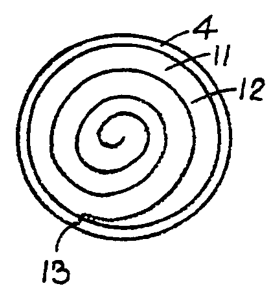

FIG. 7.

820,885 PROVISIONAL SPECIFICATION
2 SHEETS
This drawing is a reproduction of the Original on a reduced scale.
SHEETS 1 & 2

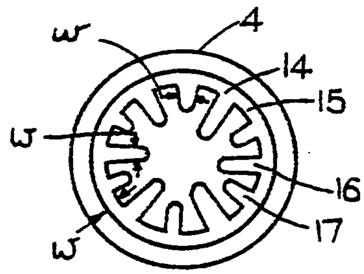

Fig. 8.

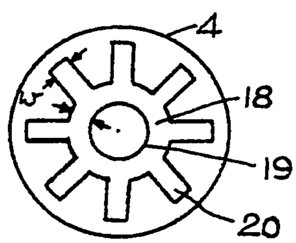

Fig. 9.

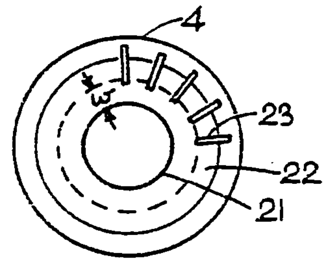

Fig. 10.

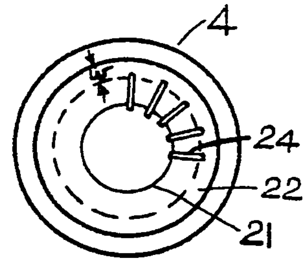

Fig. 11.

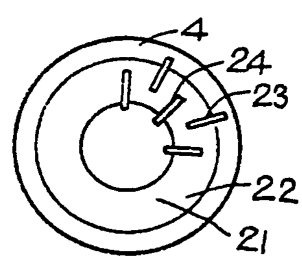

Fig. 12.

820,885 PROVISIONAL SPECIFICATION
2 SHEETS
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SHEETS 1 & 2

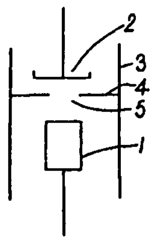


Fig.1.

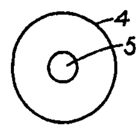


Fig.2.

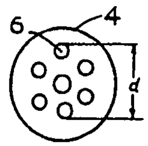


Fig.3.

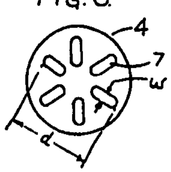
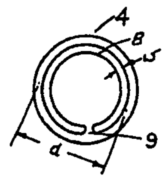


Fig.4.



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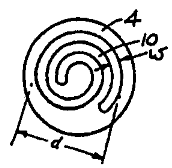

Fig.6.

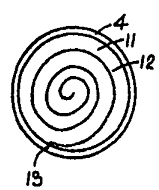

Fig.7.

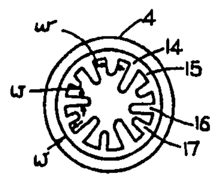

Fig.8.

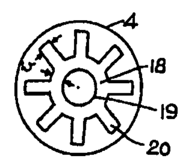

Fig.9.

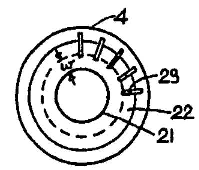

Fig.10.

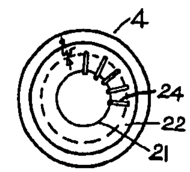

Fig.11.

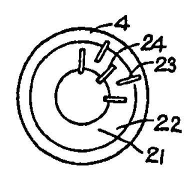

Fig 12.